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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 730
Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. PROFESSIONAL PAPERS December 24, 1918

PAPERS ON DECIDUOUS-FRUIT INSECTS

I. THE GRAPE CURCULIO
II. THE GRAPE ROOT-BORER

By FRED E. BROOKS
Entomologist
Deciduous-Fruit Insect Investigations

III. EXPERIMENTS IN THE CONTROL OF THE ROOT FORM OF THE WOOLLY APPLE APHIS

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I. THE GRAPE CURCULIO.[1]

By Fred E. Brooks,

Entomologist, Deciduous-Fruit Insect Investigations.

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INTRODUCTION.

In many localities in the eastern part of the United States the grape curculio, *Craponius inaequalis* Say (Pl. I, *A—D*), may be classed as the most destructive insect attacking the grape. From some cause or causes which are not entirely clear, the insect is markedly local in its occurrence and within the bounds of its general range appears annually in destructive numbers in some localities whereas it remains practically unknown to grape growers in other districts near by. In places where it is abundant it may be expected to destroy each year from 35 to 100 per cent of fruit on all grapevines that do not receive protection of some kind.

The adult curculio is small and inconspicuous and a grape grower will frequently lose within a short time an entire crop of fruit, that had promised well, without being able to determine the nature of the enemy that caused the loss. He will know only that the grapes while

Note.—Acknowledgment is due Mr. C. R. Cutright, who was employed temporarily by the Bureau of Entomology to assist with the present investigation.

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[1] *Craponius inaequalis* Say; suborder Rhynchophora, family Curculionidae, tribe Ceutorhynchini, subtribe Coeliodes.

growing became suddenly wormy and were ruined. Fortunately losses from this pest are easily preventable when an intelligent use is made of available means of control. The present bulletin gives an account of an investigation of this species that was carried out principally in a badly infested locality in Central West Virginia during the years 1916 and 1917.

ECONOMIC HISTORY.

This curculio seems first to have been noted as an enemy of the grape in the vicinity of Cincinnati, Ohio, in the year 1853 (2).[1] Walsh (5) states that it ruined fruit at Cobden, Ill., in the period 1863 to 1865 and at Hudson and Marietta, Ohio, from 1863 to 1867, and that in 1867 16 acres of grapes at Big Hill, Ky., were destroyed. He states also (4) that it was destructive at Carbondale, Ill., from 1864 to 1867. In 1890 Riley (15) quotes a correspondent from London, Ky., who said that the grape curculio was doing more damage than all else combined. In 1891 Webster (16) found the insect in Franklin County, Ark., and learned that it had been increasing there for at least 10 years and that it had become almost impossible to obtain crops of fruit without bagging the clusters. Brooks (30) quotes correspondents who showed that in West Virginia it was generally distributed and very destructive to grapes during the years 1899 to 1905.

SYNONYMY.

The grape curculio was first described in 1831 by Say (1) under the name *Ceutorhynchus inaequalis*, from specimens collected in Indiana, where, he states, many beetles were collected in the spring, resting upon a newly constructed fence. Le Conte (8), in his revision of Say's work, placed the species in the genus Coeliodes, but later (11) erected for it the genus Craponius. The synonymy, therefore, is as follows:

Ceutorhynchus inaequalis Say, 1831 (1).
Coeliodes inaequalis (Say) Le Conte, 1869 (8).
Craponius inaequalis (Say) Le Conte, 1876 (11).

COMMON NAMES.

On account of the larva's habit of attacking the seed as well as the pulp of the fruit, the common name "grape-seed weevil" was applied to the species by early writers. At present the common name "grape curculio" is in general use.

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[1] Numbers inclosed in parentheses refer to "Bibliography," p. 16.

DISTRIBUTION.

The grape curculio has been recorded from the New England States (33) to Minnesota (25) and south to Missouri (7) and Florida (33). Within this range there are records of its occurrence in the following States: Arkansas, Florida, Illinois, Indiana, Kentucky, Minnesota, Missouri, New York, North Carolina, Ohio, Pennsylvania, Tennessee, and West Virginia.

FOOD PLANTS.

The adult curculios may be found upon the foliage and the larvæ within the fruit of probably all kinds of wild and cultivated grapes that grow in the localities where the insect is found. There are no records of either the adults or larvæ attacking under natural conditions the leaves or fruit of plants other than the grape. During the present investigation frequent search was made for the feeding marks of the beetles on the foliage of various kinds of plants, but they were not found elsewhere than on grape, nor were the beetles or the larvæ found about any other fruit. Brooks (30) states that beetles in confinement, when deprived of other food, fed on apple and cherry leaves and that one such female deposited an egg in the fruit of Virginia creeper (*Ampelopsis quinquefolia*). This egg hatched but the larva died at the end of two days.

RECENT INJURIES.

During the present investigation the following records were made showing the destructiveness of the curculio at French Creek, W. Va.: On August 14, 1916, several clusters of fruit were picked from an unsprayed Concord grapevine. The clusters bore 163 berries and of these 161 contained curculio stings. At least one-half of the berries had already dropped from the clusters on account of being infested with curculio larvæ. On August 18 of the same year the entire crop of fruit from another unsprayed Concord grapevine was gathered. The vine produced 2,382 fruits and of these 2,274, or 95.47 per cent, showed curculio injury and 108, or 4.53 per cent, were sound. Probably half the grapes originally on the clusters had dropped as a result of infestation, and were not counted.

On August 23, 1917, about 50 grapevines of different varieties growing about farmers' homes in the locality were examined. Counts showed that from 40 to 95 per cent of all unprotected fruit had been ruined by the curculio, the average loss being about 70 per cent.

RESISTANCE OF CERTAIN GRAPES TO CURCULIO ATTACK.

Opportunity was taken to note the extent of curculio injury to about 25 different varieties of cultivated grapes and to three species of wild grapes. The wild species were the fox grape (*Vitis labrusca*), the "pigeon" grape (*V. aestivalis*), and the "frost" grape (*V. cordifolia*). Under similar conditions one variety of cultivated grape will suffer about equally with another. Frequently a discrimination will seem to be shown by the curculio between varieties, since the fruit of one vine may be attacked more extensively than that of another in the same locality. Such discrimination, however, is usually due to the particular locations of the vines rather than to any varietal peculiarities. The fruit of vines trained on the side of a house or of those growing in isolated positions in a field will escape injury to a far greater extent than will that of groups of vines trained on wire, fence, or trellis. Of the wild species the fox grape suffers about equally with the cultivated varieties, the "pigeon" grape to a less extent, and the "frost" grape is very rarely attacked. The immunity from attack of this last species is probably due to its small size and to the fact that it develops much later in the season than do the other species.

THE LIFE CYCLE IN BRIEF.

The beetles appear upon grape foliage in the spring and feed for ten days or two weeks on the upper epidermis and parenchyma of the leaf before beginning to deposit eggs within the young fruit. The larvæ (Pl. I, *H*) from the eggs feed upon the pulp and seeds of the fruit until full grown when they leave their feeding place and pupate within pellet-like earthen cocoons (Pl. I, *J*) located at or just beneath the surface of the ground. In about three weeks the beetles issue from the cocoons and go to the grape foliage, where they feed rather freely on the upper surface of the grape leaves until cool weather in the fall drives them into hibernation.

A few relatively unimportant departures from the foregoing rule are recounted later in this paper.

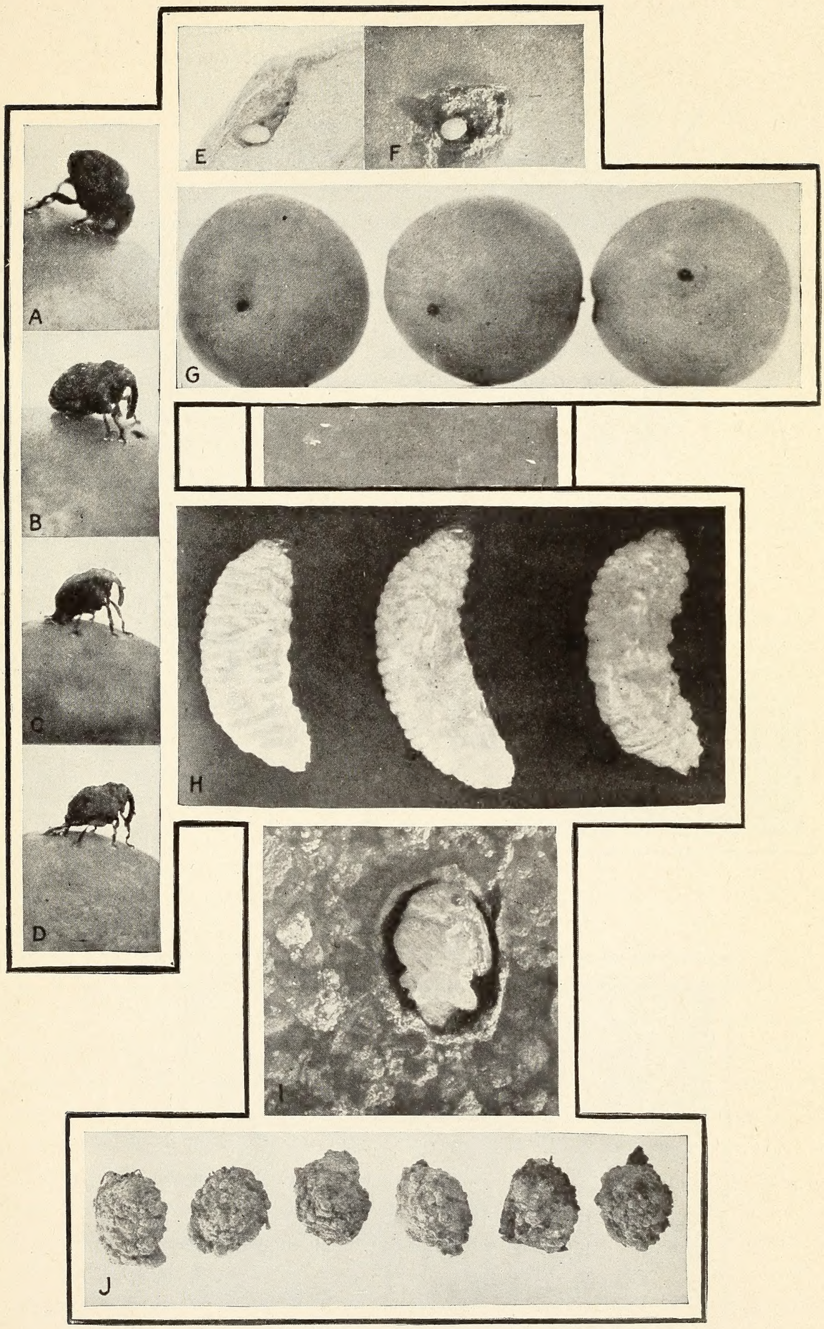
DESCRIPTION.

THE EGG.

The eggs (Pl. I, *E*, *F*) are rather uniformly oblong elliptical in shape. The surface is smooth and opaque, white when first deposited, but turning to yellowish on the second and third days. The average measurement of 10 specimens was 0.46 by 0.71 mm. The egg is attached to the wall of a roomy cavity which the female beetle with her snout excavates from the pulp of the grape through a small hole made in the skin.

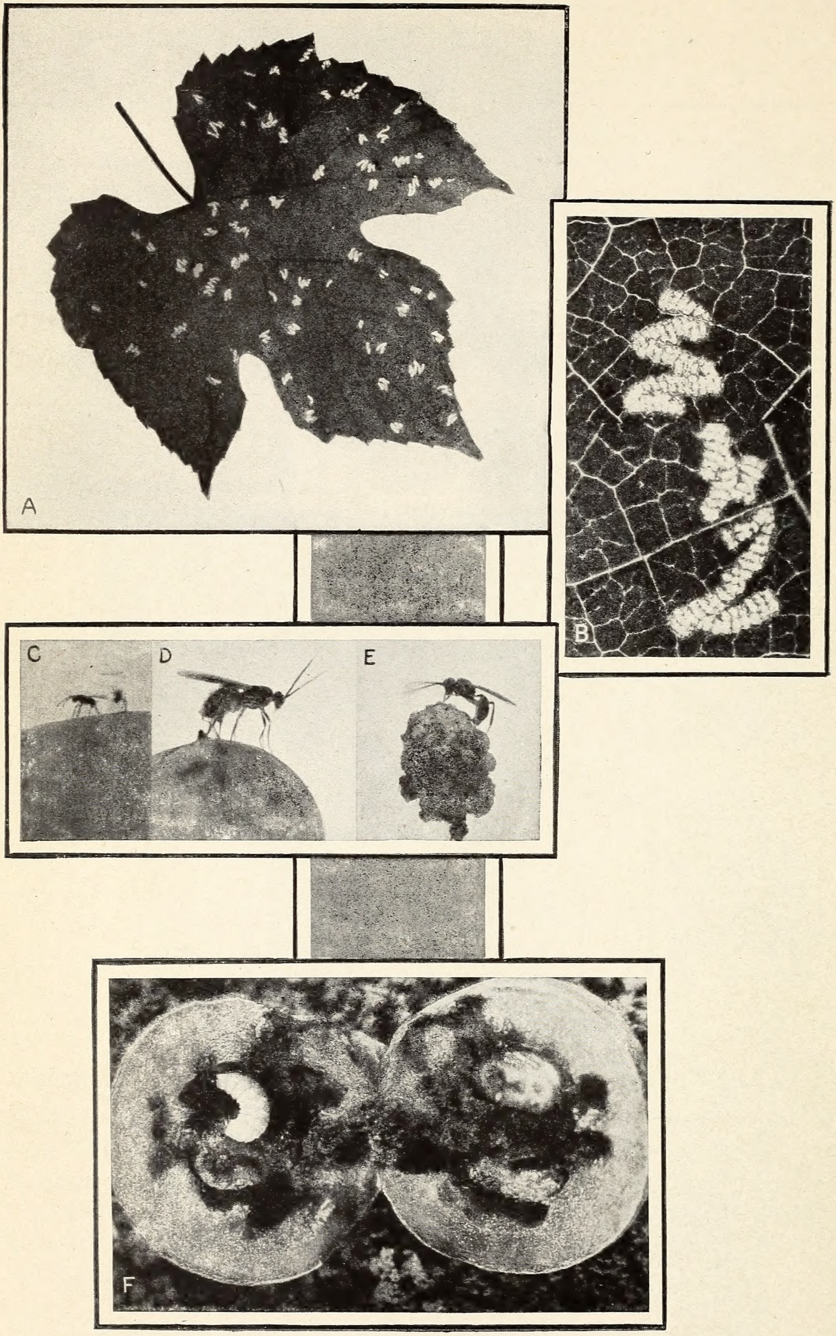
THE LARVA.

The legless, fusiform, curved larva (Pl. I, *H*; Pl. II, *F*) is white with light brown head, the body usually being clouded with the dark-colored contents of the alimentary canal. The average length is 7 mm. and



THE GRAPE CURCULIO.

A, Grape curculio excavating egg chamber; B, beetle resting by puncture in grape; C, beetle ovipositing; D, beetle sealing egg chamber; E and F, curculio eggs in natural position in grape; G, egg punctures in grapes after being sealed; H, larvæ; I, pupa in cocoon in soil; J cocoons. All enlarged. (Original.)



THE GRAPE CURCULIO AND ITS PARASITES.

A, Feeding marks of curculios in grape leaf, natural size; B, feeding marks, greatly enlarged; C, *Anaphoidea conotracheli* in act of ovipositing; D, *Microbracon mellitor* ovipositing in infested grape; E, *Stiboscopus brooksi* ovipositing in curculio cocoon; F, grape cut open to show injury by curculio larva. All enlarged except A. (Original.)

the width, at the widest point, 2 mm. The body is sparsely covered with short, fine hairs.

THE PUPA.

The pupa (Pl. I, *I*) is short, stout, and yellowish white, with the eyes and tip of rostrum reddish and with other dark markings developing as the adult stage is approached. The length is 3 mm. and the width 2 mm. The head and body are sparsely covered with long, stiff hairs. The pupa occupies a small, spherical cocoon formed of grains of earth, the cell having a delicate membranous lining.

THE ADULT.

The beetle (Pl. I, *A–D*) is short, robust, 3 mm. in length by 2.5 mm. in width, the snout being half as long as the body. The color, when fresh from the cocoon, is almost black, fading with age to chocolate brown. The surface is coarsely sculptured with prominent, acute tubercles on the thorax and elytra and the entire body is clothed with minute, whitish, scale-like hairs.

HABITS AND ACTIVITIES OF THE BEETLES.

At about the time Concord grapevines are blooming the grape curculio beetles emerge from hibernation and appear upon the grape leaves. Within the geographical range of the species the date of the first appearance of the beetles on the vines will vary considerably, according to season and locality. In West Virginia the dates of their first observed appearance on the vines are as follows:

Year.	Date.
1904	June 1
1905	May 25
1916	June 14
1917	June 2

Blatchley and Leng (33) record the beetles from central Florida from February 11 to April 13. At first the beetles are somewhat inactive and an individual may remain on a single leaf for a week or more at a time, feeding at intervals on the upper surface and sheltering during unfavorable weather on the underside. Feeding on the exposed part of the foliage is engaged in rather freely from the first appearance of the beetles in the spring until the fruit is ripe, thus rendering the beetles susceptible to arsenical sprays at any time while the fruit is on the vines. Food is also taken in a limited way from the bark of the fruit stems and the females devour the tissues removed in making their egg punctures (Pl. I, *G*) in the fruit. The immature grapes probably never are attacked by the beetles primarily for food, but the ripe fruit is sometimes punctured for this purpose.

The beetles frequently rest on the leaves for long intervals without motion and, even when eating or crawling about, their movements are so slight or so slow as not to attract attention. In appearance a beetle on the vines resembles more closely a small lump of brown earth than any form of animate life. While collecting, the writer has frequently mistaken them for the pellets of excrement dropped by sphinx caterpillars on the grape leaves. When disturbed they do not run or fly directly but leap to a considerable distance and either take wing while in the air or fall to the ground, simulating death. When caught and held closely in the hand they give forth a squeaking note pitched on an exceedingly high key. This note is heard also during sexual attempts of the male.

FEEDING MARKS.

The feeding marks on the leaves (Pl. II, *A*) are situated on the upper surface and extend only through the epidermis and parenchyma. Usually they are in the form of a slightly curved line, averaging about 2 mm. long by 0.5 mm. wide, or of from 2 to 10 such lines, joined at the ends to form acute angles. Under magnification the lines show distinct cross figurations. (Pl. II, *B*) These marks on the leaves usually may serve as the best means of determining the presence of the curculio in any locality, since in badly infested districts, especially in the autumn, the foliage is thickly specked with them. The health of the vine is not impaired to any appreciable extent by even great numbers of the marks, but this feeding habit is otherwise important as furnishing an easy means of control.

Careful measurement of 50 feeding marks showed that the average area covered by each was 3 square millimeters. In order that some idea of the individual feeding capacity of the beetles might be gained, 24 pairs were confined in jars and supplied daily with fresh grape leaves and fruit. Every morning counts were made of the marks on the leaves eaten by each pair. This was continued from July 9 to September 30, a period of 84 days. On the last-named date feeding was discontinued, all the beetles having died or entered hibernation. Table I shows the results of these counts.

TABLE I.—*Number of feeding marks made in grape leaves by 24 pairs of the grape curculio during the period from July 9 to Sept. 30, 1917.*

Pair No.	Number of feeding marks.	Pair No.	Number of feeding marks.
1	1,128	13	1,333
2	1,404	14	1,225
3	431	15	1,180
4	1,076	16	1,127
5	1,084	17	1,139
6	1,292	18	688
7	704	19	1,180
8	1,233	20	1,222
9	1,311	21	1,297
10	874	22	1,201
11	1,164	23	1,549
12	1,413	24	972
		Total	27,227

The records in Table I cover only a portion of the active life of the beetles, and it is certain that the specimens under observation had been feeding on the grape foliage for at least four weeks just prior to July 9, the day of the first record. It is also reasonably certain that at least a part of the beetles had fed for a time during the previous autumn before going into hibernation. On the day of the first record 280 feeding marks were made and the period of greatest feeding activity extended from that date to August 10. This was likewise the period of greatest egg production. On July 30 the beetles made 1,085 feeding marks, which was the maximum number, and on July 31 they deposited 244 eggs, which was also the maximum number. As is shown by Table I, the total number of feeding marks was 27,227, an average of slightly over 567 for each individual. The aggregate leaf surface eaten over by each beetle averaged slightly more than 2½ square inches and the total surface eaten by all the beetles would cover an area nearly four times the size of the printed portion of this page.

RELATIVE FEEDING CAPACITY OF THE SEXES.

During the egg-laying season the food consumed by a female in excavating her egg chambers is considerable, often surpassing daily in weight that of the insect itself. It was thought possible that the amount of fruit pulp eaten in this operation would result, for the time at least, in a decreased amount of leaf feeding by the females and render them less susceptible to arsenical sprays than are the males. Experiments, however, showed that the females do not decrease their leaf feeding during the oviposition period, and that, on the contrary, during days when egg production is heaviest leaf feeding may increase rather than diminish.

For a period of 14 days, from August 8 to August 21, 3 male and 3 female beetles were confined in cages separately and supplied daily with fresh grape leaves and fruit. During the period the males made 251 feeding marks, an average of 83.66 each, while the females made 313 marks, an average of 104.33 each. In addition, the 3 females excavated 125 egg chambers. The individual female which laid the greatest number of eggs made, also, the greatest number of feeding marks, the numbers being 54 eggs and 172 feeding marks. In another experiment, while 5 males were making 1,875 feeding marks an equal number of females under the same conditions made 2,185 feeding marks and excavated 717 egg chambers. It is thus seen that the opportunity for killing the females by poison sprays applied to the foliage during the egg-laying season is at least as good as for killing the males.

EGGS AND OVIPOSITION.

The eggs are placed singly in cavities eaten out of the fruit, the cavities averaging slightly more than 1 mm. deep by 2 mm. wide. (Pl. I, *E*, *F*) The wound is relatively large, and, even in cases where the eggs do not hatch, the hardening of the tissues about the cavity, which take place during the healing process, ruins the fruit for all purposes except that of juice extraction.

In ovipositing the female selects with some care a point, which may be at any place on the surface of the grape, and makes a small opening through the skin with her snout. Without changing her position on the grape she then excavates through the small opening all the pulp within convenient reach of the snout, the completed cavity extending back beneath the body of the beetle. (Pl. I, *A*) All the pulp removed is swallowed, and excrement is voided in small quantities during the operation. When the cavity is finished the beetle turns around, as though on a pivot, and places the tip of the abdomen over the opening in the skin. (Pl. I, *C*) On several occasions as the beetle was in the act of turning, a section of the grape was cut away by the observer so as to expose the lower end of the egg chamber, thus permitting oviposition to be watched from within through a hand lens. This showed, immediately following the appearance of the tip of the abdomen at the opening, a slender ovipositor extended and moved about touching the sides of the chamber. The ovipositor was then withdrawn into the body, but a few seconds later it was suddenly extruded to its full length and pointed rigidly forward, and at this time the movement of the egg could be seen passing down the duct. The tip of the abdomen at the moment was in contact with the wall of the chamber at the point farthest from the opening in the skin, and the egg was ejected and attached at this point (Pl. I, *E*), after which the ovipositor was slowly withdrawn into the body.

After the egg is deposited the beetle ejects a mass of excrement over the opening in the skin (Pl. I, *D*), presses some of the more solid matter of the excrement into the opening with the tip of the abdomen, and then moves away. This excrement soon dries and seals the cavity (Pl. I, *G*). Frequently the female is attended by a male during the preparation of the egg chamber and the work is interrupted by copulation. Table II shows how the time was observed to be divided in six instances where the duration of the different steps was recorded.

TABLE II.—*Time spent in oviposition by the grape curculio.*

Beetle No.	Minutes excavating.	Minutes copulating.	Minutes ovipositing.	Total minutes.
1	7	22	3	32
2	16	0	7	23
3	17	17	3	37
4	18	18	3	39
5	12	13	2	27
6	24	16	2	42
Average	15.6	14.3	3.3	33.3

There are occasional but rare departures from the method of procedure in egg laying as just described. For example, two or three egg chambers were found containing two eggs each, and on one occasion a female was observed to complete her egg chamber and then deposit an egg on the grape near the puncture. She then pushed the egg into the opening with her snout and sealed the chamber in the usual manner. A few eggs were found in excavations in the fruit stems, but the larvæ which hatched from them were not able to subsist on the food at hand.

OBTAINING EGG RECORDS.

For obtaining egg records a large number of beetles were collected from grape foliage early in the season and confined with food in cages. As fast as they could be found mating in the cages they were removed and confined by pairs in glass tumblers. The tumblers were covered with cheesecloth and the beetles provided daily with fresh leaves and fruit. Twenty-four pairs were thus obtained and kept in an open insectary throughout the season. So far as could be determined, by comparing the activities of the beetles in the glasses with those of beetles in the field, egg laying proceeded in the insectary in a normal manner.

Every morning counts were made of the eggs deposited during the preceding 24 hours. Table III shows the result of these counts and is believed to represent with fair accuracy the individual egg-laying capacity of the beetles.

TABLE III.—*Egg-laying record of 24 female grape curculios.*

Date.	Beetle No.—																								Total.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
July 3	1	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	4
4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
5	1	0	0	0	0	2	0	0	2	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	7
6	6	1	0	2	0	3	0	0	1	0	0	0	0	0	3	0	0	0	2	0	3	0	2	0	23
7	4	2	4	2	4	3	1	1	5	0	0	0	3	0	1	0	2	3	3	0	2	1	0	0	41
8	5	4	2	4	3	6	3	4	4	1	3	5	3	0	4	0	7	4	4	3	3	5	5	4	86
9	4	4	3	4	0	5	4	3	4	1	0	0	5	3	5	1	0	5	1	1	3	0	0	5	61
10	5	1	0	7	6	4	0	3	4	2	0	1	2	3	4	2	7	3	3	1	4	2	4	3	71
11	4	4	3	6	3	10	0	2	4	0	0	2	7	4	4	0	5	5	4	4	2	7	1	3	84
12	4	5	3	6	4	6	7	5	5	1	3	5	5	3	0	3	7	4	2	4	4	3	5	3	97
13	8	6	4	7	2	7	6	4	5	2	4	1	4	1	5	3	5	4	5	0	4	4	4	6	101
14	7	5	4	9	4	9	9	7	6	5	4	4	6	6	5	6	6	5	7	6	7	7	4	5	143
15	8	5	3	6	7	10	3	5	6	5	4	5	8	6	5	6	6	6	6	6	4	3	5	4	132
16	9	9	5	6	10	9	6	8	7	4	6	8	7	6	7	5	8	7	6	7	6	8	6	5	165
17	6	7	5	8	5	9	4	6	6	5	4	7	8	5	6	6	8	4	6	6	5	6	5	5	142
18	6	5	4	5	6	9	9	4	4	5	4	8	6	7	5	6	4	6	5	5	3	8	5	3	132
19	7	8	3	8	9	9	9	7	7	7	8	5	9	9	9	9	5	4	4	10	8	6	8	6	174
20	10	5	6	12	11	11	9	9	7	8	4	11	11	8	8	8	5	8	7	6	7	6	8	5	190
21	7	9	6	13	8	11	9	5	6	8	8	9	7	11	8	7	8	8	7	7	6	11	9	5	193
22	10	8	6	8	8	11	10	8	7	9	6	8	10	7	7	9	9	8	9	9	5	5	9	6	192
23	9	9	7	10	10	12	5	8	8	8	6	10	11	8	9	5	9	7	6	10	6	7	10	5	195
24	9	10	5	14	10	12	12	10	10	7	8	10	11	10	11	12	4	10	7	10	6	12	12	7	229
25	9	7	9	10	10	10	7	8	7	9	8	10	11	9	9	9	10	8	9	8	5	8	9	6	205
26	12	10	8	14	12	12	11	9	8	9	7	10	9	9	8	7	9	8	9	11	6	10	11	7	226
27	9	8	8	9	12	12	12	7	8	10	5	10	13	11	10	10	10	8	7	9	5	8	11	4	216
28	8	8	2	12	7	10	7	4	0	4	8	8	5	6	6	6	5	7	6	10	4	5	7	5	150
29	10	8	10	12	11	13	12	10	12	10	4	11	8	12	12	11	11	7	8	12	6	8	13	2	233
30	10	8	6	10	11	8	12	9	8	8	9	10	13	9	8	9	8	12	9	10	7	11	9	10	224
31	12	12	6	16	14	15	10	7	6	8	6	12	12	9	12	13	11	8	8	11	7	11	13	5	244
Aug. 1	9	8	7	14	10	14	12	9	7	4	9	7	14	11	10	11	12	10	10	11	8	12	8	6	233
2	10	9	6	9	11	11	5	5	6	1	7	8	9	5	7	8	6	5	7	8	5	6	11	6	171
3	6	5	4	8	6	6	3	6	4	0	3	6	6	8	4	4	4	4	5	4	5	5	8	4	118
4	6	7	4	8	5	7	4	3	5	0	6	4	6	7	6	1	8	4	7	6	4	6	8	4	126
5	12	8	6	10	10	10	9	8	6	0	6	10	9	8	8	1	9	7	8	7	7	12	8	1	180
6	8	7	5	12	8	12	8	7	5	0	2	7	8	7	7	0	10	5	4	8	5	8	7	2	152
7	5	7	4	8	9	7	5	2	5	0	8	6	6	5	8	0	6	4	10	6	6	3	8	4	132
8	6	6	5	8	6	8	7	3	5	0	4	7	6	7	3	2	7	6	5	5	4	3	4	3	120
9	7	5	3	8	8	8	6	3	4	0	4	7	7	6	6	1	7	5	6	5	2	7	9	4	128
10	3	4	4	6	4	7	5	4	5	0	1	4	4	4	4	0	4	5	4	4	3	4	4	3	90
11	5	4	2	6	4	6	4	4	4	0	3	6	5	5	4	1	3	3	4	6	2	4	4	2	91
12	4	5	5	9	9	6	1	1	5	0	3	7	7	8	2	4	8	7	3	6	3	8	3	7	121
13	4	3	4	9	4	8	7	2	2	0	2	5	6	3	2	0	6	6	4	6	3	6	2	4	98
14	2	7	3	8	5	8	7	1	1	0	2	8	6	6	0	1	6	4	4	5	4	6	1	2	97
15	3	3	3	8	2	6	3	1	3	0	2	5	3	5	1	0	4	4	4	6	2	7	0	2	77
16	0	5	2	6	3	10	3	3	6	0	0	7	5	6	0	2	5	5	0	4	0	6	0	1	79
17	2	4	4	8	4	5	3	2	5	0	1	5	3	7	0	0	4	6	6	3	2	6	0	2	82
18	0	1	2	3	2	2	1	0	0	0	0	2	3	2	0	0	0	4	1	5	1	5	0	0	34
19	0	3	2	2	2	4	1	1	4	0	0	4	2	4	1	0	2	4	1	2	0	9	0	2	50
20	0	0	2	3	0	1	1	2	3	0	2	0	2	2	0	0	1	4	2	4	0	9	0	0	38
21	0	0	0	3	2	2	0	1	1	0	0	0	1	2	0	0	0	4	3	2	0	5	0	0	26
22	1	0	1	0	0	0	0	1	0	0	0	0	1	3	0	0	0	5	0	2	0	5	0	0	19
23	0	0	2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	4	1	2	0	7	0	1	18
24	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	3	0	2	0	3	0	0	9
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	3	0	0	4
26	0	0	0	1	0	0	0	1	0	0	0	0	0	2	0	0	0	2	0	0	0	1	0	0	7
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2	0	0	3
28	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1	1	0	1	0	0	1	0	0	1	7
29	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	1	0	5
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Sept. 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	295	269	202	378	301	386	274	223	245	141	185	286	313	285	248	191	282	283	249	285	196	321	262	180	6,280

As indicated in Table III, the total number of eggs laid by the 24 females was 6,280. The minimum number laid by an individual was 141 and the maximum number 386, the average for the 24 beetles being 261.66.[1] The first eggs were deposited on July 3 and the last on September 5, oviposition by all the beetles covering a period of 65 days. The greatest number of eggs laid by a female in a single day was 16, and this record was made in only one instance. Another beetle laid 15 eggs in a day and there were six cases in which 14 eggs were laid in a day. The period of greatest egg production was from July 13 to August 12, 81.9 per cent of the eggs being deposited between these dates. The maximum number of eggs for one day was 244; these were produced on July 31.

ACTIVITY OF THE BEETLES AT NIGHT.

During the progress of the investigation it became apparent that the beetles were ovipositing and feeding on the leaves to some extent during the night, and, to obtain data on this point, 5 pairs of beetles were confined in cages in the insectary on July 19 and kept under observation until August 3, a period of 14 days. The beetles were provided with fresh grapes and leaves three times daily, at 5 a. m.,[2] 12 m., and 7 p. m., the duration of the forenoon period being 7 hours, that of the afternoon period 7 hours, and that of the night period 10 hours. Each time the grapes and leaves were changed in the cages counts were made of the eggs and leaf-feeding marks produced during the period just ended. The counts showed a total of 455 eggs produced by the 5 females for the entire period. Of this number 85 were deposited during the forenoon period, 148 during the afternoon period, and 222 during the night period. The average was 16.6 eggs for each of the 14 hours of daylight and 22.2 eggs for each of the 10 hours of darkness. Feeding on the leaves was more active by day than by night. The 10 beetles during the daylight periods made 1,072 feeding marks, or an average of 78 for each of the 14 hours of daylight, and 376 during the night period, or an average of 37.6 for each of the 10 hours of darkness.

TIME REQUIRED FOR EGGS TO HATCH.

About 50 eggs deposited on July 17 hatched on July 23 and an equal number deposited on July 21 hatched on July 27, the period of incubation in both cases being 6 days. Differences in temperature probably would produce a variation of a day or two in the length of this period.

All the eggs of a female that had been separated from males for 33 days were found to be fertile, although in nature copulation continues at frequent intervals until the end of the egg-laying season.

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[1] It is interesting to note that the average number of eggs laid by 30 females from which a record was obtained in 1905 (30) was 257.46, a difference per individual for the two lots of beetles of only 4.2 eggs.

[2] All references to clock time refer to "Standard time."

ACTIVITIES OF THE LARVÆ.

The young larvæ begin to feed on the grape berry before they are free from the eggshell and within a few minutes after emergence from the shell burrow out of sight within the pulp. On the second or third day they attack the seed and on the fourth day practically all the larvæ are located within the seed cavity of the grape berry. Later they leave the seed cavity and continue to feed on the pulp, soon converting the interior of the grape into a discolored mixture of pulp and excrement. (Pl. II, *E*)

Larvæ reached full growth and issued from the grapes in from 13 to 25 days after the deposition of the eggs. Table IV shows the number that appeared on each day.

TABLE IV.—*Number of days elapsing from deposition of eggs by the grape curculio to issuance of larvæ from the grapes.*

Number of days in grape	13	14	15	16	17	18	19	20	21	22	23	24	25
Number of larvæ issuing	2	5	51	71	29	37	17	10	11	7	1	3	3

According to Table IV, allowing 6 days for the eggs to hatch, the larvæ remain in the grapes from 7 to 19 days, the average time being from 10 to 12 days.

The larvæ squeeze through small holes which they make in the skin of the grape berry and seek at once for places in which to pupate. Most of the larvæ leave the grapes during the morning hours, although a few continue to appear during the afternoon. On August 4, 1917, 57 larvæ dropped from a basket of infested grapes suspended in the vineyard over a container. At the end of every hour the larvæ in the container were collected and counted. The results are shown in Table V.

TABLE V.—*Time of day in which larvæ of the grape curculio leave grape berries.*

[Standard time.]

	A. M.								P. M.		P. M. to A. M.
Hours of day	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12	12–1	1–2	2–4
Number of larvæ	0	2	7	17	13	5	2	5	5	1	0

Table V indicates that more than one-half of the larvæ leave the grapes to pupate between the hours of 7 and 9 in the morning. Most of the cocoons are constructed on the surface of the ground except in cases where the larvæ follow cracks or other openings into the soil. They are frequently placed under fallen leaves or other small objects and are sometimes attached to straws or stones lying on the surface of the ground.

THE PUPA PERIOD.

Small lots of larvæ which had just issued from grapes were placed in jars containing earth on August 1 and 2, 1917. From these larvæ 46 beetles developed, of which 37 emerged on the eighteenth day and 9 on the nineteenth day. This and other observations indicate that in the warmer part of the summer the beetles issue, on an average, about 18 days after the construction of the cocoon. The larvæ that leave the grapes late in August and in September pupate and remain within the cocoon until the spring following, when they issue as beetles at about the time the wintering beetles are emerging from hibernation.

THE BEETLES IN THE FALL.

The young beetles that appear late in summer spend all the remaining warm days of the season on the grape foliage. They feed rather freely and can be distinguished very readily from the old beetles which are still on the vines by their fresher appearance and darker color. Many of the beetles that appear from hibernation or from wintering pupæ in the spring live through the entire season and enter hibernation again in the fall. Of the lot of 48 beetles kept in glass tumblers for the purpose of obtaining egg records throughout the summer of 1917, 36 were still alive on October 4. At that time the 36 beetles were placed in a large jar containing dry, decayed wood and soon thereafter they hid away in the wood fragments and became dormant. There is considerable mortality among the beetles soon after they appear upon the vines in the spring, and the probability is that most of the beetles that die at that time are the individuals that have survived two winters.

NATURAL ENEMIES.

PREDACIOUS FORMS.

At the time the grape curculio larvæ leave the grapes and crawl over the ground in search of suitable places to pupate, they fall an easy prey to ants and other enemies. In the summer of 1917 a small red ant, determined by Wheeler as *Solenopsis molesta* Say, was observed in great numbers feeding on larvæ beneath infested grapevines. Another ant, determined by Wheeler as *Aphaenogaster fulva* Roger, subspecies *aquia* Buckley, variety *picea* Emery, was present in less numbers and was observed attacking the larvæ. A small ground-dwelling spider, as yet undetermined, was seen to pounce upon a curculio larva and was caught as it hurried with its load beneath a stone. The larva of a rove beetle, *Philonthus brunneus* Gravenhorst, and the following species of ants are recorded as attacking the curculio larva: *Camponotus pennsylvanicus* De

Geer, *Myrmica punctiventris* Roger, *Lasius americanus* Emery, *Cremastogaster lineolata* Say, and *Solenopsis debilis* Mayr.

PARASITES.

In August, 1916, it was found that many of the curculio eggs were being destroyed by a minute hymenopterous parasite, determined by Girault as *Anaphoidea conotracheli* Girault Pl. (II, *C*), a well-known egg parasite of the plum curculio, *Conotrachelus nenuphar* Herbst. This parasite is about half a millimeter in length and is barely visible to the naked eye. The legs and bases of antennæ are light brown and the rest of the body is black. In 1917 this parasite was again abundant and was observed frequently ovipositing in the curculio egg punctures in grapes. When a fresh puncture was made by the grape curculio several of these egg parasites would collect about it and could be seen through a lens, thrusting their ovipositors through the skin of the grape into the curculio eggs in the egg chamber. Males usually were present and copulation would take place while the females were struggling with one another for a desired position over the egg chamber. Adult parasites issued in from 10 to 13 days after their eggs had been deposited within the eggs of the grape curculio. When the mature parasites leave the host eggs they sometimes enter the pulp of the grape and mine through it to the surface, making a threadlike burrow half an inch or more in length. The exit hole of the parasite in the skin of the grape is usually near to the original puncture of the curculio.

In determining the extent of parasitization by this species, about 50 curculio beetles were confined on July 24, 1917, in a wire-screen cage over a live branch of grapevine bearing 8 bunches of sound fruit. Two days later the cage and curculios were removed and the punctured grapes left exposed for six days to the attacks of the egg parasites. A later examination showed that 134 curculio eggs had been deposited in the grapes and of these 53, or 39.5 per cent, had been parasitized. The oviposition period of the curculio is sufficiently long for the development of four or five successive generations of the parasite. This may account for an apparently constant increase in the percentage of parasitized curculio eggs as the season advances.

Another parasite, *Microbracon mellitor* Say (Pl. II, *D*) was observed frequently ovipositing in infested grapes on the vine and on the ground. The larva of this species attacks the larva of the curculio externally and devours it, after which it constructs within the grape a small, dirty-white cocoon from which the adult parasite escapes within a few days. A third hymenopterous parasite, *Stiboscopus brooksi* Ashm. (Pl. II, *E*), attacks the curculio while within the cocoon. This parasite is about 4 mm. in length, the ovipositor being one-third as long as the body. The head and thorax are shining black, the abdomen brown, the tips of antennæ dark brown, and the bases of antennæ and the legs light brown. It runs rapidly over the ground under infested grapevines, frequently crawling beneath fallen leaves and into openings in the ground in search of curculio cocoons. When one is found the parasite manifests much excitement and runs about over the cocoon, with both antennæ and ovipositor applied to the surface, in search of a vulnerable point of attack. When such a point is located the ovipositor is thrust viciously to its full length within the cocoon, after which the insect remains quiet for a few seconds while the egg is being deposited. The parasitic larva destroys the curculio within the cocoon and issues as an adult within a short time. Both this species and *Microbracon mellitor* were abundant in the locality where the present investigation was carried out. A single specimen of still another parasite, which has been determined by Mr. R. A. Cushman as *Triaspis curculionis* Fitch, was reared from the grape curculio in 1917.

METHODS OF CONTROL.

SPRAYING.

The long period during which the curculio beetles feed freely on the upper surface of the grape leaves renders them peculiarly susceptible to arsenical sprays. In several cases practically complete freedom from attack was obtained by applying two sprays of lead arsenate at a strength of 3 pounds of the paste to 50 gallons of water, the first just after the blossoms had dropped and the second three or four weeks later. In August, 1917, a count of several thousand fruits of different varieties of grape from sprayed vines showed that only a little more than 1 per cent of the fruit was infested, while on unsprayed vines in the same locality from 75 to 90 per cent of the fruit was punctured.

On July 26 a Concord grapevine was sprayed with lead arsenate at a strength of 3–50. As soon as the spray was dry a branch of the vine bearing leaves and several bunches of sound fruit was inclosed in a wire-screen cage in which 50 male and female curculio beetles had been placed. Four days later, when the cage was removed, all the beetles were dead. The grapes which had been in the cage contained 8 eggs and there were about 50 feeding marks on the leaves, indicating that the death of the beetles resulted from a small amount of feeding. At about the same time another grapevine was sprayed with a tobacco extract containing 40 per cent of nicotine as sulphate at the rate of 1 pint to 800 gallons of water, and a fruiting branch inclosed with 40 beetles. At the end of 4 days 38 of the beetles were still alive in the cage, 119 eggs had been deposited in the fruit, and 1,136 feeding marks had been made on the leaves.

It is possible to destroy the beetles by spraying with arsenicals at any time during the growing season of the fruit, or in the fall after the fruit has been gathered. Preferably, however, a spray shuold be applied in the spring soon after the blossoms have dropped and another three or four weeks later. This is the season when other grape insect pests and fungous diseases are to be dealt with and the sprays can be prepared and applied for combined results. As has been pointed out, the beetles are feeding on the foliage for 10 days or more before oviposition begins and practically all may be killed by spraying before any injury is done to the fruit.

BAGGING.

Inclosing the clusters of fruit when about one-fourth grown in 1-pound or 2-pound paper bags affords complete protection against the curculio. The ordinary paper bags kept by grocers are sufficient for this purpose. The bags should be slipped over the clusters and the mouth pinned or otherwise fastened securely around the stem. The bags usually remain intact until the fruit is ready for gathering, and the grapes within ripen perfectly. This method of protecting the fruit, however, is much slower and more expensive than is spraying, and for protecting the fruit from the curculio the results are very little, if any, better than would be obtained by spraying.

OTHER METHODS OF CONTROL.

Cultivation of the soil under infested grapevines destroys the curculios to some extent by breaking up the cocoons and exposing the pupæ, or by burying the cocoons so deeply in the soil that the beetles on emerging from the cocoons are unable to work their way to the surface.

A measure of benefit also may be obtained by gathering and destroying the punctured fruit and by collecting the beetles by jarring them from the vines in the early morning or on cloudy days upon sheets spread on the ground beneath the vines.

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II. THE GRAPE ROOT-BORER.[1]

By Fred E. Brooks, *Entomologist, Deciduous-Fruit Insect Investigations.*

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INTRODUCTION.

The studies of the grape root-borer (*Memythrus polistiformis* Harris) described herein were conducted principally at French Creek, W. Va., during the summers of 1916 and 1917. Conditions there were favorable for the investigation, since the insect occurred abundantly and over a hundred badly infested grapevines were at the entire disposal of the investigator. Wild grapes of the species *Vitis labrusca*, *V. cordifolia*, and *V. aestivalis* abounded also in the locality, affording an opportunity for observations as to native host plants.

The grape root-borer in all its stages is peculiarly inconspicuous, and there is a possibility that the species is a more widespread and serious enemy of grapes than has been commonly supposed. The eggs (Pl. III, *E*) are small and dark-colored and are so placed by the female moth that they escape notice, the larvæ (Pl. III, *A*, *B*) feed exclusively on the roots and throw no castings to the surface of the ground, pupation takes place within the soil, and the adults (Pl. III, *C*, *D*) so closely resemble wasps of the genus Polistes that the casual observer does not distinguish between them and true wasps. Grapevines are rarely killed outright by the borers, but, on becoming infested, usually linger for years, making meager annual growth and bearing reduced crops of fruit (Pl. V). There is a probability that many vineyards suffer seriously from this insect while persons in charge of the vines remain unaware of the true cause of the trouble.

Note.—The author wishes to acknowledge the assistance of Mr. C. R. Cutright, field assistant in the Bureau of Entomology, in conducting the investigation described herein.

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[1] *Memythrus polistiformis* Harris; order Lepidoptera, family Aegeriidae.

ECONOMIC HISTORY.

The grape root-borer is a native of the eastern part of the United States, and doubtless bred originally in the several species of wild grapes indigenous to that region. It was first described in 1854 by Harris (1, 2),[1] who recorded injury by the species in North Carolina. In 1867 Walsh (3) wrote of the species at some length and reported injury in Kentucky, Missouri, North Carolina, and Ohio. He quotes a correspondent who said he had noted injury by the root-borer in Missouri for 20 years. Riley (4), in 1871, mentioned the destructiveness of the species in Kentucky and recorded capturing the moths in Missouri. In 1873 Glover (5) reported, on the authority of a correspondent, that 5,000 vines, representing 107 varieties imported from Paris and planted at Albemarle, N. C., were lost as a result of attacks by this borer. Lugger (6) states that a single moth of this species was seen flying about a wild grapevine in Minnesota in 1898. Holland (7), in 1903, mentioned the range of the moth as extending as far north as Vermont. Brooks (8), in 1907, wrote of serious injury by the species in central West Virginia.

GEOGRAPHICAL DISTRIBUTION.

The grape root-borer has been recorded as occurring in the States of Kentucky, Minnesota, Missouri, North Carolina, Ohio, West Virginia, and Vermont. It very probably will be found in other States, where the inconspicuousness of the insect and its work have resulted so far in its being overlooked.

FOOD PLANTS.

Grapevines, so far as known, are the only plants attacked by this insect. Apparently all the common cultivated varieties of the eastern part of the country suffer about equally in this respect. Vines of the fox grape, *Vitis labrusca,* growing in a vineyard, were found to be attacked almost as extensively as Concord and other cultivated sorts, although vines of the same species growing in woods were not injured seriously. Vines of *V. cordifolia* and *V. aestivalis* were not observed to be attacked. The Scuppernong, a variety of the Southern fox grape, *Vitis rotundifolia,* is said by a correspondent of Glover (5) to have withstood attacks.

RECENT INJURIES.

During the past 10 years the writer frequently has observed serious injury by the grape root-borer in a few sections of West Virginia. Vines have been seen in other localities which had every appearance of being infested, but, since the borers can be found only by digging to the vine roots, no examination was made and positive evidence of their presence is lacking. A number of old vines are known that have been infested constantly for at least 10 years. In cases where these vines have been pruned, cultivated, and fertilized a strong annual growth of wood is still made and the crops of fruit are satisfactory. Infested vines when neglected, however, in all cases observed have practically ceased growing and died by degrees over a period of several years.

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[1] Numbers in parentheses refer to "Literature cited," p. 28.

NATURE OF INJURY.

Injury to grapevines by the root-borer is due exclusively to the burrows made by the larvæ in the roots (Pl. III, *A*, *B*), and is usually in the nature of severe root-pruning. The newly hatched larvæ enter the ground in the vicinity of grapevines and penetrate the soil in search of roots, attacking them wherever found. Usually roots smaller in diameter than an ordinary lead pencil are not made a place of permanent attack. Those half an inch in thickness, and often those that are larger, are girdled or eaten entirely off, only a stump of live root being left to help sustain the vine. Frequently all the main roots of a vine will be severed at varying distances from the root center. In such cases the remaining root stumps hasten to send out branch roots, the vigor and extent of growth of the branches depending largely upon the cultural care the vine is receiving at the time.

DESCRIPTION.

THE EGG.

(Pl. III, *E*.)

The egg is 1.1 mm. long by 0.7 mm. wide, chocolate brown, oblong ovate, and flattened; one end is slightly truncate, and a broad furrow extends longitudinally on one side. The surface, except in the furrow, is finely and distinctly reticulate.

Eggs hatch in from 18 to 23 days.

THE LARVA.

(Pl. III, *A*, *B*.)

When first hatched the larva is dingy brown and about 2 mm. in length. After the first or second molt the color changes to white. The head is brown and the body is distinctly segmented and covered sparsely with short, stiff hairs. Full-grown specimens are from 35 to 40 mm. in length. The larva stage covers a period of nearly two years.

THE PUPA AND COCOON.

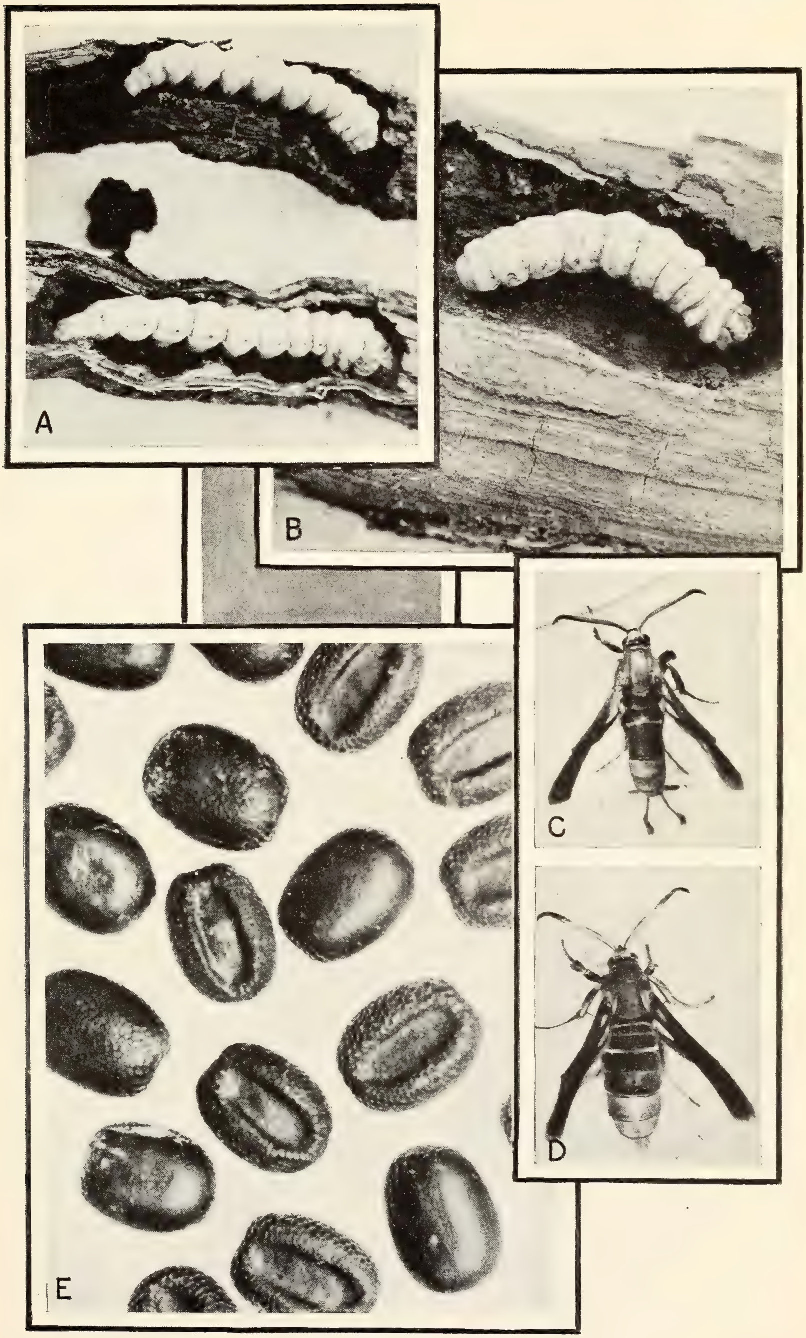
(Pl. IV, *A*, *B*.)

The pupa is dark brown, with bands of a lighter shade encircling the abdomen. Its average length is 20 mm. It occupies a cocoon at the surface of the ground, usually directly over the point in the root where the full-grown larva ceased feeding. The pupa is characteristic of its family, being spindle shaped, the males having 14 and the females 13 rows of strong reflexed dorsal spines, the cremaster consisting in each of 8 stout spines surrounding the anal end. The cocoon is from 20 to 30 mm. in length and stands perpendicularly in the soil with the anterior end just at the surface of the ground. It is composed of frass and grains of earth held together with a parchment-like lining of brown silk. Usually, although not always, more grains of earth than of frass enter into the composition of the outer part of the cocoon. The pupæ and cocoons of the females average longer and stouter than those of the males. When the moth is ready to issue it works half the length of the pupa out of the cocoon and escapes from the pupa case through a slit in the back, leaving the empty case projecting above the ground. (Pl. IV, *B*.) The insect occupies the cocoon for a period of about four weeks.

THE ADULT.

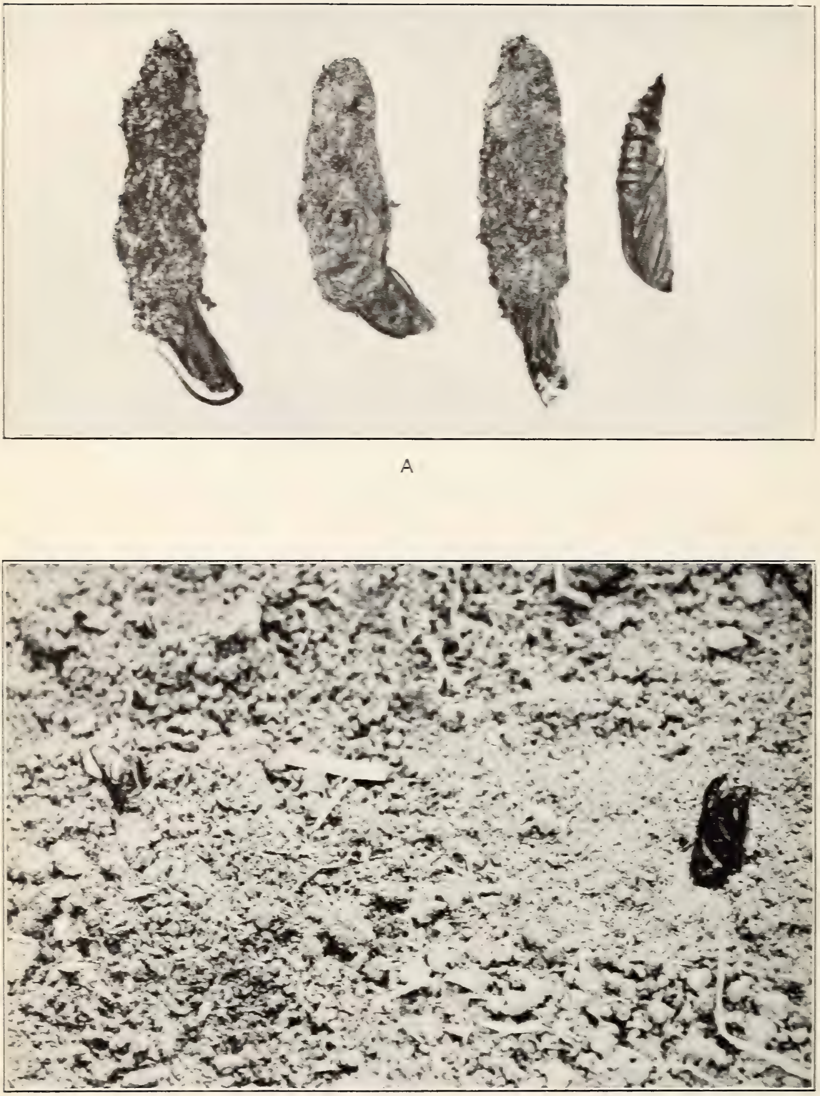
(Pl. III, *C*, *D*.)

The mature insect is a handsome, wasplike moth, the males of which are from 12 to 18 mm. in length, and the females from 18 to 20 mm. The general color of both sexes is dark lustrous brown. The fore wings are brown and the hind wings transparent bordered and veined with brown. The abdomen is encircled at the posterior margins of the second and fourth segments with conspicuous bands of orange and lemon colored scales, the lemon scales predominating in the front band and the orange in the other. There are spots of metallic yellow scales at the base of the wings. The legs are reddish brown. The antennæ of the males are brown, marked with metallic colors and are delicately pectinate; those of the female are brown for a third of the length at the base, the rest metallic purple and bronze. The female has a small orange-colored tuft on each side of the tail and the male has two such tufts on each side, the middle pair being more than twice as long as the others. The scales with which the moths are covered rub off easily and old specimens rarely show all the markings described above.



THE GRAPE ROOT-BORER.

A, B, Larvæ feeding in grape roots (A, natural size; B, enlarged); C, male moth, slightly enlarged; D, female moth, slightly enlarged; E, eggs, greatly enlarged. (Original.)



A

B

THE GRAPE ROOT-BORER.

A, Pupa, cocoons, and empty pupa cases: B, empty pupa cases projecting from ground under grapevine. Slightly enlarged. (Original.)

THE GRAPE ROOT-BORER.

Old grapevine showing small growth and light crop of fruit due to injury. (Original.)

ACTIVITIES OF THE MOTHS.

It has been stated that in North Carolina the moths are on the wing from the middle of June until the middle of September (3) but observations indicate that in West Virginia the period of flight is not so long. Table I shows the dates on which moths were first and last seen in three different years in West Virginia.

Table I.—*Period moths of the grape root-borer are on the wing, West Virginia.*

Year.	First seen.	Last seen.	Number of days on wing.	Average number of days.
1907	July 24	Aug. 10	18	23.3
1916	July 20	Aug. 17	29	
1917	July 25	Aug. 17	24	

The records set forth in Table I show that in the locality where the present investigation was made the moths are probably on the wing a little less than 30 days, instead of 90 days, as reported from North Carolina.

The moths issue from the cocoons on bright, warm days, usually about the middle of the forenoon. Of 11 females observed, all left the cocoons between 9 a. m.[1] and 11 a. m. The males after issuing rest for a while on some object near the discarded cocoon and then take flight, but the females are less active and usually remain quietly near the place of emergence several hours to await the coming of the males. Several females that were kept under observation were seen to elevate their genitalia, evidently sending forth a scent to attract males. Almost instantly after this act was begun by the female a swarm of males would appear and copulation would soon take place. Usually the pair would remain connected for 2 or 3 hours, and on the morning following egg laying would begin. In one case observed copulation lasted 2 hours and 45 minutes and in two cases 3 hours and 40 minutes each. Two or three of the females did not attract and receive the males until the morning following their emergence from the cocoons. One group of excited males that gathered around a female contained a single male of the squash-vine borer, *Melittia satyriniformis*. This moth grasped the female and attempted to pair with her after she had united with a male of her own kind.

In ovipositing the females make short flights, alighting on the canes or leaves of grapevines, or, more frequently, on grass, weeds, or straws under or near the vines, and deposit in each place one or more eggs. Sometimes four or five eggs will be placed together and at other times the female will crawl over the surface of a leaf or along a grape cane or weed stem, pausing every few inches to deposit an egg. No attempt is made to conceal the eggs, except that the moth occasionally will move along the margin of a leaf and bend her abdomen over the edge, placing eggs on the underside. The eggs are attached very feebly, and the rain or wind soon dislodges them and they fall to the ground before hatching. One female kept in a cage produced 555 eggs and several others more than 400 each. About a week is required by the female in which to deposit her quota of eggs. Females caught in the vineyard while ovipositing and placed in bottles continued to drop eggs with scarcely any intermission resulting from the changed conditions.

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[1] References to clock time refer to standard time.

As has already been mentioned, there is a close resemblance in the moths to the comb-building wasps of the genus Polistes. The gravid females are somewhat more deliberate in flight than are the wasps, but the males dart about on the wing in a manner that is very wasp-like. The males have a habit of resting for long periods in exposed positions about the vines, and when approached or disturbed frequently flutter their wings rapidly, giving off a buzzing sound that still further increases their resemblance to wasps. Rarely the female also will engage in this buzzing performance.

Bottles in which females had been kept in the insectary, and in which they had been seen to elevate their genitalia, were several times taken to the vineyard after the females had been removed. When uncorked, males would appear almost immediately, evidently attracted by the scent, and would even enter the bottles in search of the females.

LARVAL ACTIVITIES.

The larvæ hatch from eggs that at the time are almost invariably scattered over the ground in the vicinity of grapevines. After hatching they at once burrow into the soil and attack the larger grape roots whenever found. It is possible that they subsist on small roots and root fibers while searching for their permanent places of attack, but undoubtedly many of them perish before finding roots to their liking. They enter the roots wherever they come in contact with them, either close to the vine or far out toward the extremities. In one case a larva was found that had penetrated a foot of stiff clay soil and attacked a root at a point 19 feet from the vine.

The ability of the larvæ to penetrate the ground to a considerable distance was shown by placing a large number of hatching eggs on the surface of soil that had been placed to a depth of 9 inches over some sections of grape root in the bottom of a wooden box. Twenty days later the grape roots were removed and the bark found to be filled with young borers. The borers had mined an inch or more in the bark, some of the burrows encircling the roots and others extending parallel with the grain of the wood.

As the larvæ increase in size the burrows become large and irregular in outline, and roots that are half an inch or less in diameter usually are eaten off or injured so severely that the outlying section dies. Very large roots may withstand the combined attacks of several borers without being killed. Such large roots are usually eaten most extensively along the underside.

The larva passes the winter in a roomy chamber at the end of its burrow, the chamber being sometimes, although apparently not always, lined with a very thin web of silk. Feeding is not continued through the winter, but is resumed as soon as the soil becomes warm in the spring.

When full grown the larva makes an open passage from its feeding place upward through the soil to the surface of the ground, where the cocoon is constructed. The larva in some way transports from the root considerable frass for use in making the cocoon. Evidently after the cocoon is begun the larva passes back and forth frequently from the cocoon to the root, probably feeding on the root at intervals and voiding the frass while working at the cocoon. Pupation takes place in June and early July.

NATURAL ENEMIES.

No parasites of this species are known. During the present investigation ants were seen carrying the moth eggs, but what disposition they made of them was not observed. In a previous study of this species (8) the writer found the larva of a firefly beetle (*Photuris pennsylvanica* De Geer) which had broken into a root-borer cocoon and was devouring the pupa. The crested flycatcher (*Myiarchus crinitus*) was observed to catch several moths on the wing.

METHODS OF CONTROL.

This species does not lend itself readily to any of the common insecticidal methods of control; neither is the worming process, so often used against various borers attacking fruit trees, of practical application against this species. The borers feed in the roots over so wide an area that digging for them as a practicable method of destruction is out of the question and even soil fumigants are, for the same reason, of doubtful value.

Thorough cultivation of the soil around the vines during June and July is of some benefit in destroying the larvæ and pupæ in the cocoons. By far the most valuable practice, however, is the application of such cultural methods as would induce in a healthy vine a vigorous and rapid growth. It was found that even badly infested vines, when carefully pruned, sprayed, fertilized, and cultivated, made a normal wood growth and bore satisfactory crops of fruit. The borers, by killing the terminals of so many of the roots, greatly restrict the feeding area of the root system, and it becomes necessary to use fertilizers rather freely within a few feet of the vine, where most of the roots are located. The use of fertilizers and the application of the other cultural methods mentioned become increasingly important as the root injury increases.

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1907. The grape-vine root-borer. West Va. Agr. Exp. Sta. Bul. 110. 3 p., [5] pl.

Account of an investigation of the species in West Virginia.

III. EXPERIMENTS IN THE CONTROL OF THE ROOT FORM OF THE WOOLLY APPLE APHIS.[1]

By B. R. Leach, *Scientific Assistant, Deciduous-Fruit Insect Investigations.*

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INTRODUCTION.

During the seasons of 1914 and 1915 a series of experiments on the control of the root form of the woolly apple aphis (*Erisoma lanigerum* Hausmann) was conducted in Virginia, the work being based on the results obtained by French investigators in the employment of carbon disulphid and sodium cyanid in solution against the grape phylloxera. The opportunity also was afforded of obtaining data on the use of kerosene emulsion and on the effect of deep planting as preventives of woolly apple aphis injury.

Little work appears to have been done by American entomologists in the employment of carbon disulphid and sodium cyanid in solution as a control for soil-inhabiting insects. The data obtained as a result of the experiments herein reported are presented in the hope that other experimenters will have opportunity to carry out further tests along these lines. Much additional information concerning these treatments is desirable, especially that which may be acquired through experiments carried on under a variety of climatic, crop, and soil conditions.

THE USE OF CARBON DISULPHID IN WATER.

EARLY RECORDS.

The use of carbon disulphid in water was first proposed by Cauvy,[2] of France, in 1875.

It was found that a solution containing from 0.5 to 1.2 per cent of carbon disulphid will kill the grape phylloxera in 24 hours. The advantages claimed for the method are that it is harmless to the vine, even in full vegetation, and that by its use a uniform distribution of the carbon disulphid in the soil is effected. It is stated, however, that the disadvantages of this treatment are the enormous amount of water required and the high labor cost.

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[1] *Eriosoma lanigerum* Hausmann; order Hemiptera, suborder Homoptera, family Aphididae.

[2] Bourcart, E. Insecticides, Fungicides and Weedkillers. p. 74. London, 1913.

No record has been found of the use of this method in the United States.

EXPERIMENTAL WORK WITH THIS METHOD.

Realizing the possible merits of this method of applying carbon disulphid, a series of determinative experiments was carried out during the seasons of 1914 and 1915. The resulting data, herewith presented, include an account of the preliminary work to determine the factors influencing this water treatment and a report of the large-scale operations in the field in which this method was utilized, based on the knowledge acquired in the preliminary experiments. In conclusion, a discussion of the advantages and disadvantages of the treatment is given.

Preliminary Experiments.

PREPARATION OF THE BASIN.

In applying quantities of liquid for the control of soil-inhabiting insects, such as the root form of the woolly apple aphis, it is necessary, in order that the material may be effective, to prepare a basin around the base of the tree for the reception of this liquid in order that it may be spread evenly over the soil surface, and to insure permeation and absorption by the soil.

In preparation for the reception of the carbon-disulphid solution the basin should be made as shallow as possible, to prevent exposure of the roots. If the roots are exposed, the gas in solution is prevented from acting upon the aphids thereon, and the treatment is thereby rendered incomplete. The bottom of the basin should be absolutely level, with the soil heaped up around the edges to confine the liquid to the area undergoing treatment.

In order to simplify the placing of the liquid, strips of galvanized iron, shown in Plates VI and VII, were utilized. These strips were 12 feet in length and 5 inches in width, providing for a circular basin 4 feet in diameter. After leveling the ground about the base of the tree one of the strips of galvanized iron was placed with the ends overlapping 3 or 4 inches (Pl. VI) and the dirt heaped up around the outer edges. This gave a level basin for the reception of the liquid and confined it to the area to be treated.

AMOUNT OF LIQUID REQUIRED IN THE TREATMENT AND THE INFLUENCE OF SOIL TYPE AND SOIL MOISTURE.

The success of this treatment depends on the one essential, that sufficient liquid be used. Experiments carried out for the purpose of obtaining data on this point demonstrated the general efficiency of three-fourths of a gallon of liquid per square foot of soil area treated. This is equivalent to about one and two-tenths inches of water.

This quantity of liquid, in the majority of cases in moist soils, and regardless of the soil type, will penetrate to reach the aphids infesting the roots at the lower levels. This condition is due to the difference in the depth of infestation in the various soil types by the woolly aphis. In general it may be said that the root infestation by this insect occurs at greater depths in light soils—for instance, the shale loams—than is the case in heavy soils, such as the clay loams. On the other hand, a given quantity of liquid will be absorbed to a greater depth by a light soil than by a heavy soil. It may be said, therefore, that a given quantity of liquid will penetrate a given soil in proportion to the depth of the aphis infestation in that soil. For this reason a standard recommendation can be made as to the quantity of liquid required for all soil types.

The treatment may be used in either dry or moist soil, but is less laborious in the latter. If the ground is well drained, the best results are obtained after a heavy rain, when the soil is saturated, since a given quantity of liquid will penetrate deeper in moist soil than in dry soil, thereby resulting in a more thorough control.

When the liquid is applied to dry soil, most of the liquid (when used at the rate of three-fourths gallon per square foot) is taken up and retained by the first few inches of dry top soil. In order to insure the death of the aphids in the lower levels of the soil under these conditions it is necessary to use a much larger amount of liquid per square foot of area treated, with a consequent increase in labor and cost.

THE PREPARATION OF THE LIQUID AND DETERMINATION OF MOST EFFICIENT DOSAGE.

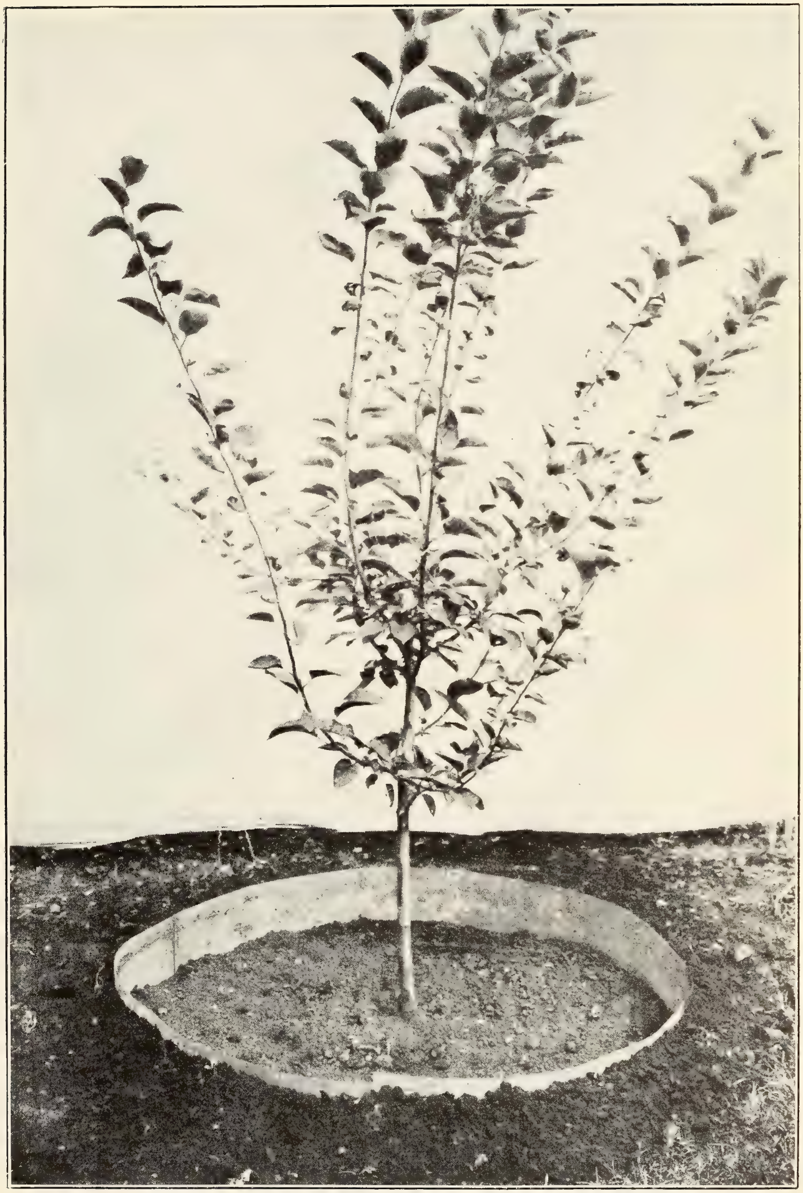
When carbon disulphid is added to water, and the mixture is allowed to settle, the carbon disulphid drops to the bottom of the container and collects in a single large globule. By agitation with a broad paddle the carbon disulphid may be broken up into globules which diffuse to every portion of the liquid. Some of the carbon disulphid goes into solution while the remainder forms a mechanical mixture with the water.

The small amount of carbon disulphid dissolved in water necessary for the success of this method is remarkable. The following experiment will illustrate this point: A one-fourth inch stream of water at 60° F. was led to the bottom of a column of carbon disulphid 18 inches in depth, contained in a glass cylinder, and allowed to diffuse upward through the carbon disulphid, thereby taking up the carbon disulphid in solution. This solution was immediately collected and placed in sealed bottles until used at the rate of three-fourths gallon per square foot for the control of the root form of the woolly apple aphis. This extremely dilute solution, although less than 1 to 1,000, gave perfect control.

In consideration of the foregoing data, a dosage at the rate of one-half ounce of carbon disulphid to 4 gallons of water was rated as the most efficient, and this was verified subsequently in practice. One-half ounce of carbon disulphid is more than can be dissolved in 4 gallons of water at ordinary temperatures. When the liquid is agitated, the portion of the material not entering into solution forms a mechanical mixture with the water. A margin of safety is thereby secured which insures the success of the treatment. *Under no circumstances is it necessary to employ a stronger dosage than the foregoing.* In fact, when larger doses are used the excess carbon disulphid drops to the bottom of the container, despite agitation, thereby resulting in an uneven strength and consequent danger of injury to the roots.

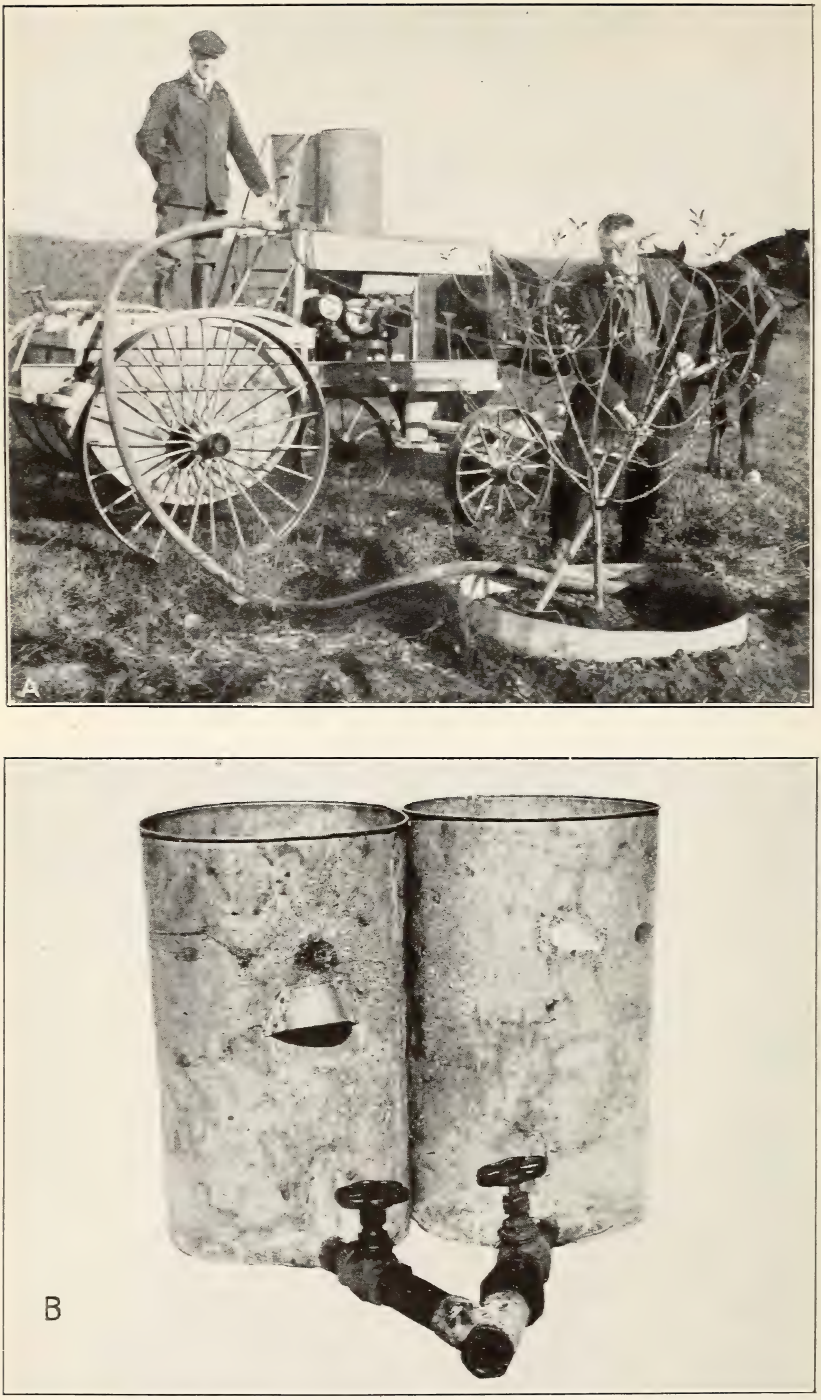
THE DIFFUSION OF THE LIQUID AND CONTAINED GAS IN THE SOIL.

During the course of the work the question arose as to whether the carbon-disulphid gas given off from the water diffused laterally beyond the point in the soil attained by the water itself, and a series of experiments was carried out to determine this point. Figure 1 shows the method employed. The soil treated with the liquid was confined to the circular area 4 feet in diameter within the galvanized-iron strip *D*. The galvanized-iron strip may therefore be taken to represent the line of demarcation between the soil within the strip, directly subjected to the action of the liquid, and the soil outside the strip which remains in its natural state of dryness, except for any possible lateral diffusion at this immediate line of demarcation between the two. At points *A*, *B*, and *C*, respectively, 2, 4, and 6 inches from the strip, screen-wire cylinders containing apple roots infested with the woolly apple aphis were placed in the ground previous to the application of the liquid. When examined 5 days later, the aphids at *A*, *B*, and *C* were alive and breeding. This experiment was carried out in (1) light and (2) heavy soils, both in dry and in moist condition, with the same results. On several occasions the examination of treated trees showed that aphids on the roots located just outside the treated area had escaped, thus corroborating the results of the specific experiments previously outlined. It is apparent, therefore, that the carbon-disulphid gas in the solution does not diffuse laterally through the soil beyond the point reached by the liquid.



CONTROL OF THE ROOT FORM OF THE WOOLLY APPLE APHIS.

A basin for the reception of carbon-disulphid solution, using a strip of galvanized iron. (Original.)



CONTROL OF THE ROOT FORM OF THE WOOLLY APPLE APHIS.

A, The employment of a power-spraying outfit and auxiliary tanks for the application of carbon-disulphid solution in orchard practice; B, the auxiliary tanks. (Original.)

INJURY TO THE TREE.

Apple trees in the first year of growth were treated at the height of the growing season with varying dosages of carbon disulphid in water.[1] One ounce of carbon disulphid to 4 gallons of water caused considerable injury, as evidenced by the drying of the foliage, but did not kill the tree, while 2 ounces to 4 gallons of water killed the tree in three days.[2] Since one-half ounce of carbon disulphid to 4 gallons of water is ample for control there is no necessity for increasing the strength.

In the same way apple trees in their second year of growth were treated with varying dosages of carbon disulphid in water.[1] One ounce carbon disulphid to 4 gallons of water caused no injury, 1½ ounces caused considerable injury, and 2 ounces killed the tree outright in 10 days.[3]

The increased resistance of the older trees is explained by the greater area involved by the root mass, a large part of which was not subjected at all to the fumes of the carbon disulphid.

During the extended field tests about 500 apple trees of varying ages were treated at the rate of one-half ounce of carbon disulphid to 4 gallons of water and no apparent injury resulted.

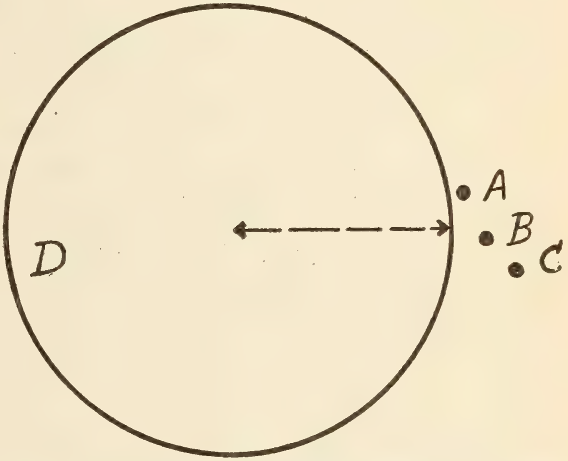


Fig. 1.—Diagram illustrating method of determining the lateral diffusion through the soil of carbon disulphid in water. For explanation see p. 32. (Original.)

Injury to the tree by carbon disulphid in large doses is first indicated by a drying of the foliage. This, however, is merely direct evidence that the small roots and rootlets have been injured, thus cutting off the normal supply of water to the leaves and causing them to turn brown. With medium doses rootlets killed by carbon disulphid are rapidly replaced by the otherwise unimpaired root system. With the dosages of one-half ounce to 4 gallons of water the rootlet injury is negligible, and no killing of the foliage or check in growth will result.

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[1] Liquid employed at rate of three-fourths gallon per square foot of soil area treated (p. 31).
[2] Diameter of treated areas in these tests 30 inches.
[3] Diameter of treated areas in these tests 48 inches.

THE BEST TIME OF APPLICATION.

Trees were treated at intervals throughout the season to determine the effect of carbon-disulphid solution when applied at the varying stages of seasonal development. With the possible exception of early spring, when the trees are producing their initial foliage, no noticeable injury was observed. Treatment at this time appeared to delay the process of leafing out. With this treatment it is a question of securing ideal conditions of soil moisture, and not essentially a question of season.

LARGE-SCALE TREATMENTS, USING THE LIQUID METHOD.

As a result of the foregoing work experiments involving large numbers of trees were undertaken. These large-scale operations required the employment of a 200-gallon power-spraying outfit and the special galvanized-iron tanks shown in Plate VII. The method of preparing and disposing the solution was as follows:

Having half filled the spray tank with water, the required amount of carbon disulphid, at the rate of one-half fluid ounce to 4 gallons of water, was poured into the tank and the agitation started and continued while the remainder of the water was being run into the tank. The agitation was continued while the outfit was being driven from the source of water supply to the location of the trees to be treated, and by this time the water in the tank was evenly charged with carbon disulphid in solution and in suspension as a mechanical mixture.

The tree basins for the reception of the liquid having been previously prepared, the material was run out through the tanks placed on the top of the engine hood (Pl. VII, *A*) to the basins about the trees. In order to secure accuracy in measuring the liquid, the heights in these tanks representing 4 and 8 gallons were indicated by black circles painted on the inside.

These two auxiliary galvanized-iron tanks (Pl. VII, *B*), having a capacity of 12 gallons each, were connected by a 2-inch Y-pipe to the discharge hose, each of the two arms of the Y-pipe being furnished with a globe valve. The liquid was pumped through a 1-inch hose directly from the 200-gallon tank, and could be directed into either of these two auxiliary tanks at the will of the operator. While one tank was being filled the liquid in the other was being run into a tree basin simply by opening the globe valve belonging to that tank. When empty, the valve was closed and the tank again filled, and during this process the contents of the other tank in turn were emptied into a prepared basin. The process was so regulated that no interruptions were necessary, and 200 gallons of liquid could be disposed of in from 15 to 20 minutes.

A crew of three men was required—a driver, a man to operate the filling and emptying of the tanks, and a man to distribute the water evenly over the surface of the basin.

One tank of 200 gallons was sufficient for the treatment of from 20 to 25 trees, and with a crew of three men it was possible to dispose of one tank an hour, depending on the distance from the water supply.

ADVANTAGES OF THIS METHOD.

The advantages of this method are as follows: When properly agitated every portion of the combination solution and the mechanical mixture contains the same amount of carbon disulphid. When it is poured onto the soil it sinks through the earth, carrying the carbon disulphid to every part of the soil penetrated by the liquid. This results in an even distribution and none of the aphids escape. With this method no portion of the soil receives too much or too little of the fumigant, but just enough to do the work.

DISADVANTAGES OF THIS METHOD.

The greatest disadvantage of this method is the amount of labor in handling the large quantity of water required, the employment of several horses and men being necessary for this purpose.

The difficulty, when ordinary labor is employed, of preparing the basins properly for the reception of the liquid, so as to insure an even distribution of the liquid over the soil area to be treated, is a second disadvantage. On hillsides it is almost impossible to insure the even distribution of the liquid over the surface of the basin.

On some trees, in some soils, the area of infested roots is so extended that treatment of a basin 4 or 5 feet in diameter will not reach all the aphids, and since three-fourths gallon per square foot is required for success, the amount of water necessary for the treatment of an area greater than the foregoing practically limits its use to small trees with restricted root area.

USE OF SODIUM CYANID IN SOLUTION.

EXPERIMENTS ON VINES IN FRENCH VINEYARDS.

Among the substances tried against the phylloxera in France was sodium cyanid in solution. Bourcart[1] records the experiments of Mouillefert as follows:

The stocks were stripped to a depth of about 15 centimeters, with a radius of 30 to 35 centimeters (12 to 14 inches), the soil being rather dry. After pouring on the cyanid solution the soil was replaced at the foot of the stocks and thoroughly packed. The dose varied from 20 to 25 grams per stock, dissolved in 10 liters (2.2 gallons) of water. Wherever the solution had penetrated, the phylloxera and their eggs were dead, but at a depth of 40 to 50 centimeters (16 to 18 inches), as well as between the stocks in a radial direction, even by using five times more water, the result was incomplete.

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[1] BOURCART, E. Insecticides, fungicides, and weedkillers. p. 135. London, 1913.

EXPERIMENTS AT WINCHESTER, VA.

Having prepared the basins as described for the use of carbon disulphid in solution, using 8 gallons of liquid to a 4-foot basin, one tree was treated with the solution at the rate of one-half ounce to 4 gallons of water, and the second tree at the rate of 1 ounce to 4 gallons. The aphids within the treated area were killed.[1]

PREPARATION OF THE SOLUTION.

Sodium cyanid is very soluble in water, and it is therefore not necessary to exercise the same degree of care in preparing the solution as is the case when using carbon disulphid. In the initial experiments outlined above the correct amount of sodium cyanid was weighed out and stirred into the water contained in 2-gallon pails. In the more extended field experiments the material was dissolved in a 200-gallon spray tank and run into the basins through the auxiliary tanks described under the "Use of carbon disulphid in solution."

DOSAGE EMPLOYED.

Experiments were carried out in which from one-fourth to 2 ounces of sodium cyanid to 4 gallons of water were used, and as in the case of carbon disulphid it was found that one-half ounce of sodium cyanid to 4 gallons of water was the most satisfactory.

THE EXTENT OF THE LATERAL AND VERTICAL DIFFUSION OF THE GAS BEYOND THE RANGE ATTAINED BY THE LIQUID.

The particular experiment (p. 32, fig. 1) made to determine whether the fumes of carbon disulphid diffused laterally beyond the range of the liquid was repeated with sodium cyanid. The results were the same in both instances, namely, the fumes of sodium cyanid do not diffuse laterally beyond the point attained by the liquid in its diffusion.

Experiments and observations made during the course of the work confirmed the opinion of Mouillefert, recorded above, that the gas from the dissolved cyanid did not diffuse evenly or produce aphid mortality to the lowest depths attained by the liquid in the case of carbon disulphid.

No difficulty was encountered in killing the aphids at shallow depths when the liquid was used at the rate of three-fourths gallon per square foot of soil area, but the aphids forming the deeper infestation invariably escaped. This was the case even in moist, light soils, where the foregoing quantity of water will penetrate to a considerable depth.

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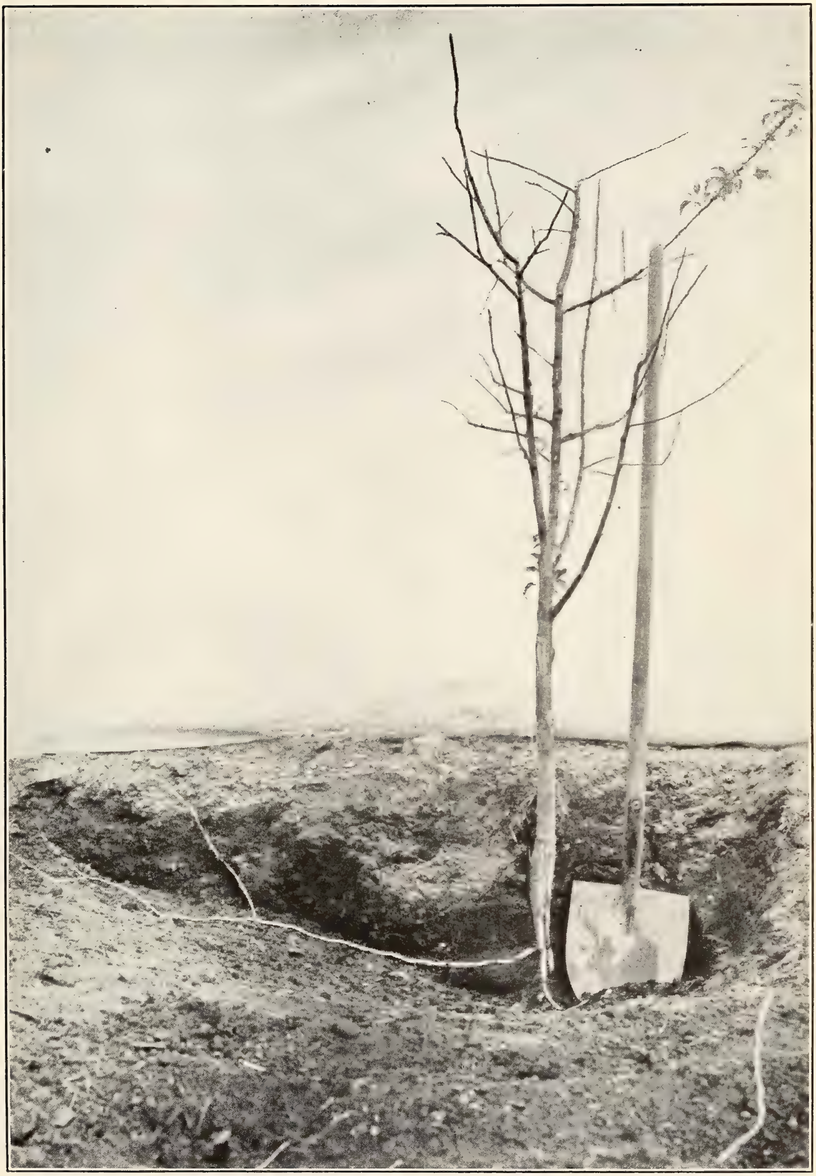
[1] The aphid infestation on these trees was shallow.



CONTROL OF THE ROOT FORM OF THE WOOLLY APPLE APHIS.

A deeply planted tree with root system exposed; top almost dead. Note the partial success of the root system in attaining the upper soil levels. (Original.)

INJURY TO THE TREE.

The trees used in the following experiments were of 1-year growth in the nursery and were planted in the spring, three months prior to the experiments outlined below, which were carried out during the height of the growing season.

4 ounces of sodium cyanid to 4 gallons of water killed the tree in 48 hours. The foliage turned brown and dried.

2 ounces of sodium cyanid to 4 gallons of water killed the tree in 7 days.

1 ounce of sodium cyanid to 4 gallons of water injured the tree, as indicated by the browning of the foliage to some extent, but it did not kill the tree, which resumed growth later in the season.

One-half ounce of sodium cyanid to 4 gallons of water produced no apparent injury nor did it check the growth. Trees treated with this dosage remained normal during the following two years and made a satisfactory growth.[1]

During the following summer, when this block of trees was in its second year of growth, trees other than the ones used in the dosage tests outlined above were treated, with the following results:

4 ounces of sodium cyanid to 4 gallons of water killed the tree in 8 days.

2 ounces of sodium cyanid to 4 gallons of water injured the foliage to some extent but did not kill the tree.

1 ounce of sodium cyanid to 4 gallons of water produced no apparent injury nor was there any check in growth.

One-half ounce of sodium cyanid to 4 gallons of water produced no apparent injury.[2]

It will be observed that the resistance of the apple to sodium cyanid in solution, as in the case of carbon disulphid, depends on the age of the tree. During the extended field tests about 500 apple trees of various ages were treated at the rate of one-half ounce to 4 gallons of water with no apparent injury. In excessive doses the same type of injury occurs as results from the employment of large doses of carbon disulphid.

ADVANTAGES AND DISADVANTAGES OF THE METHOD.

The only advantage possessed by sodium cyanid as compared with carbon disulphid is its ready solubility in water. On the other hand, its uncertainty in producing aphid mortality in the lower soil levels, together with the extremely poisonous nature of the material, precludes its use in practice.

USE OF KEROSENE EMULSION.

PRELIMINARY EXPERIMENTS.

Kerosene emulsion has been recommended repeatedly as a remedy for the root form of the woolly aphis. Experiments were therefore carried out to determine its efficiency and also to determine what takes place when the kerosene emulsion is introduced into the soil.

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[1] See footnotes 1 and 2, page 33.

[2] See footnotes 1 and 3, page 33.

For this latter purpose the following apparatus was devised: A series of pinholes was made in the bottom of a pail and the latter then filled with earth, well tamped down, and the soil scooped out slightly and heaped up against the inside of the pail so as to furnish a miniature basin for the reception of the liquid. The soil column thus prepared was approximately 7 inches in depth. Into the basin on the surface of this column was poured 10 per cent kerosene emulsion at the rate of three-fourths gallon to the square foot of soil surface, and a drip pan placed immediately beneath the pail in order to catch the drippings from the soil column. The following conclusions were arrived at as a result of this and several other similar experiments:

A. The first inch of surface soil separates out and retains all the soap in the emulsion, together with some of the kerosene content.
B. The first 4 inches of the soil retains almost all the remainder of the kerosene.
C. The drippings from the soil column 4 inches in depth consist of clear water with a slight trace of kerosene.

FIELD EXPERIMENTS.

Experiments carried out in the field, in which 3-year-old apple trees infested with the woolly aphis were used, corroborated the results obtained in the laboratory. The basins for the reception of the kerosene emulsion were prepared as outlined for the application of carbon disulphid in water, and the material was used at the rate of three-fourths gallon per square foot of soil treated. The majority of the aphids within 8 inches of the surface were killed as a result of the treatment, but those at lower levels escaped. Furthermore, the trees were very severely injured as a result of the application of the emulsion. The following spring, seven months after the treatment, the foliage presented a weak, yellowish appearance, and practically no new growth. The rootlets were badly injured and were not replaced that season by new growth.

The mechanical and unstable character of kerosene emulsion, together with the cost and labor required in preparing the quantity necessary for soil treatment, renders this method of little value.

DEEP PLANTING.

Theories have been advanced from time to time in the literature to the effect that by planting the apple tree deeper in the soil than is normally done the aphis infestation will be prevented. Evidently it is presumed that the aphids will be unable to live at the lower depths in the soil occupied by the root systems of these deeply planted trees. Furthermore, it is taken for granted that the root systems will grow normally at these depths.

The writer fortunately was enabled to make observations and photographs of the effects of deep planting, as carried out by a grower at

Winchester, Va., his object being to prevent the ravages of the woolly aphis. Following this idea he planted 200 trees, the first tier of main roots being 18 to 24 inches below the surface of the ground in a stiff clay soil. The second year after planting some of the trees began to show signs of distress, while others were growing normally. The third year some were dead, others nearly dead, and others growing normally.

An examination of the root systems showed the following conditions:

1. The root growth on the dead trees was poor. The roots had made an unsuccessful attempt to reach the upper layers of the soil. No new tiers of roots had been pushed out at a higher level in the soil.
2. The trees in a subnormal condition had succeded in pushing a few roots up to the top layers of the soil (Pl. VIII).
3. The deeply planted trees which were growing normally had succeeded in pushing the majority of their roots up to the surface layers of the soil.

When trees are planted deeply only a portion of them will succeed in pushing their roots up to the surface layers of the soil. The trees which do not succeed in accomplishing this eventually die. Deep planting is unnatural, injures the tree, and does not prevent aphis infestation.

SUMMARY.

Carbon disulphid, in solution at the rate of one-half ounce to 4 gallons of water and applied at the rate of three-fourths gallon per square foot of soil, will control the root form of the woolly aphis under suitable soil conditions. The liquid is best applied by preparing shallow basins about the tree and should be applied only when the soil is in a moist condition. The solution is best prepared by pouring the carbon disulphid into the water and agitating vigorously. The carbon disulphid thereby breaks up into small globules, some going into solution and the remainder forming a mechanical mixture with the solution. The gas diffuses laterally and vertically only as far as the liquid penetrates and therefore every square foot of infested soil must be subjected to the action of the solution in order to insure complete control. When used at the foregoing rate the carbon disulphid produced no injury to the roots of apple. The treatment may be made at any time during the growing season except during the period of two or three weeks in the spring when the trees are budding out.

In orchard practice the solution is best applied by using a power spraying outfit and two auxiliary tanks.

The advantages of this method are, first, the even diffusion of the liquid and complete aphid mortality in the soil area treated and, second, the safety with which the disulphid can be used. The disadvantages of the method are, first, the huge amounts of water required, with consequent high cost of labor; second, the difficulty, on any but level ground, of preparing basins with level floors, thus insuring the proper distribution of the liquid over the area to be treated; and, third, the wide area of infested roots on older trees, every square foot of which must be treated with the liquid. This last condition precludes the use of carbon disulphid except on small trees with restricted root areas.

Sodium cyanid at the rate of one-half ounce to 4 gallons of water did not kill the woolly aphis in the lower soil depths even when a superabundance of solution per square foot was employed. No injury to apple roots resulted when the material was employed at this strength. The only advantage this material possesses, as compared with carbon disulphid, is its ready solubility in water. On the other hand, its uncertainty in producing aphid mortality in the lower soil levels, together with the extremely poisonous nature of the material, precludes its use in practice.

When kerosene emulsion is applied to the soil it disintegrates into its component parts; the first inch of surface soil retains the soap and some of the kerosene content; the first 4 inches of the soil retains almost all the remainder of the kerosene. Kerosene emulsion, therefore, does not kill the aphids in the lower soil levels and the cost of preparing the quantity necessary for soil treatment renders it of little value. The application of this material to apple roots, in the writer's experience, results in severe injury to the tree.

Deep planting will not prevent woolly aphis infestation and results in the death of many trees so planted, due apparently to the inability of the root systems to function properly under these conditions.

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